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Milk Contributes Share to Daily Vitamin C Quota

The vitamin C content of milk is receiving increasing attention on the part of nutrition research. During 1940 scientific journals have published a number of reports on new studies concerning vitamin C in milk.

Because vitamin C is readily destroyed under certain conditions much of the antiscorbutic value of a food product may be lost before it is consumed unless special precautions are taken to prevent such loss. A quart of milk when freshly drawn from the cow contains an amount of vitamin C which approaches the daily minimum required in the human diet to prevent scurvy. Research has discovered some of the causes of vitamin C destruction and the application of these findings to commercial handling of milk makes possible the preservation and delivery to the consumer of increasingly larger portions of the original vitamin C content of fresh whole milk.

Daily Requirements for Vitamin C

Vitamin C values and requirements are usually stated in terms of international units or in terms of milligrams (one thousandth part of a gram) of l-ascorbic acid. One international unit is the equivalent of 5/100 of a milligram, or 5/100,000 of a gram. One milligram (mg.) is the equivalent of 20 international units of vitamin C.

The amounts of vitamin C required in nutrition have been estimated by a number of workers. Smith (1) reviewing the literature, in the American Medical Association's 1939 Symposium on Vitamins, states that:

> . . . for adults as well as for infants and children the range of estimated requirements from the physiologically indispensable minimum to complete saturation is extremely wide—from 25 or 30 mg. to 100 mg. daily or from about 0.4 to 1.6 mg. per kilogram of body weight—a fourfold increase from the absolute minimum to what might be called luxus consumption.

The same author (2) in another paper tabulates the estimates of vitamin C requirements according to age groups as follows:

It seems reasonably certain . . . that the minimum and maximum values which have been reported may be considered to represent a range in allowances covering requirements from the physiologic minimum, which should never be lowered, to the optimum, the state of nutrition that cannot be bettered. For the various age groups these ranges between minimum and optimum appear to be as follows in terms of daily allowances:

Infants through the age of breast feeding (from birth to 9 months)—minimum, 10 milligrams; suggested optimum, 50 milligrams.

Children, 9 months to about 6 years—minimum, increasing gradually to about 20 milligrams; suggested optimum, increasing gradually to about 100 milligrams.

Older children—no data available; the allowances for adults are suggested.

Adults—minimum, 28-30 milligrams; suggested optimum, 100 milligrams or more.

Pregnant and lactating women—minimum, at least 50 milligrams over the minimum for other adults.

Elderly people—minimum, 50 milligrams.

Munsell (3) considering results of the several methods for determining vitamin C requirements, states:

The concomitant results of such tests indicate that 20 to 25 mg. (400 to 500 I. U.) of ascorbic acid per day represents the minimum necessary to prevent scurvy, while 40 to 60 mg. (800 to 1200 units) per day is probably adequate and 80 mg. (1600 units) sufficient to meet all needs. During pregnancy and lactation the allowances should be fully twice the values given above. The requirement for children is only slightly, if any, less than that for adults, and infants may need much more in proportion to their weight than adults.

Physician Is Own Subject in Vitamin C Experiments

The approximate human requirement for vitamin C has been calculated by Crandon, Lund and Dill (4) from a case of experimental human scurvy as 30 to 45 mg. per day, which would be 600 to 900 international units. The experiment of the Harvard workers, in which one of the investigators was the subject, is discussed in an editorial in the Journal of The American Medical Association from which the following is quoted:

Physicians who serve as their own experimental animals for the elucidation of medical problems are not infrequent; they always arouse admiration and appreciation, however, even when martyrdom may not be involved. A recent example of such self experimentation is the production and thorough study of an induced case of human scurvy. The observations were made at Harvard University by Crandon, Lund and Dill; . . . the first named, an assistant in surgery at the Harvard Medical School, was the experimental subject. The diet was carefully prepared and was completely deficient in vitamin C but adequate in every other respect. Crandon spent a period of six months on this diet. While two other studies on experimental human scurvy are cited, one was not controlled and the other lasted for only a few days. This study is therefore the first in which a human being has remained on a controlled diet deficient only in vitamin C for this length of time. . . .

The earliest clinical manifestations of scurvy were hyperkeratotic papules, which were noted after 132 days on the vitamin C deficient diet; the perifollicular hemorrhages of scurvy required another month (161 days) for their appearance. There was also a noticeable fragmentation of hair. Associated with these signs was a pronounced dryness of the skin, particularly over the extensor surfaces. These manifestations suggested vitamin A deficiency, but biophotometric tests showed normal visual adaptation in the dark, thus excluding this possibility. Subjective weakness was first noted at the end of the third month and increased progressively. A rather thorough study of the fatigue was made in the Fatigue Laboratory of Harvard University. Although it was due to some underlying physiologic deficiency, an explanation was not found. The subject suffered a steady and progressive weight loss of 27 pounds (12 Kg.) . . . .

Experiment Indicates Vitamin C Requirement

The medical journal editorial explains how the physicians calculated the approximate human requirement for vitamin C as between 600 and 900 international units per day:

The disappearance of all signs and symptoms of scurvy was rapid following the intravenous injection of ascorbic acid. Saturation curves were determined each day for several days and proved most illuminating; after the first injection of 1 Gm. of the vitamin, i.e. when deficiency was complete, the plasma ascorbic acid level fell to almost zero in three hours. On the next day the same dose was injected but this time the level fell only to 0.25 mg. per hundred cubic centimeters in five hours. On the third day the same dose was injected but the level fell only to 0.75 mg. per hundred cubic centimeters even after seven hours following the injection. On the fourth day the level remained well above 1 mg. per hundred cubic centimeters, which is normal. In other words, the blood became completely saturated after 4 Gm. of the vitamin had been given intravenously, 1 Gm. on each of four successive days. Urinary excretion studies, however, indicated that the tissues were still not completely saturated at this time. These clearcut observations have obvious diagnostic as well as therapeutic implications. For example, the authors have calculated the approximate human requirement of the vitamin as lying between 30 and 45 mg. a day. This was determined by dividing the 4 to 6 Gm. needed to saturate the subject by 132 days, the period of total deprivation required to produce clinical scurvy.

Here then for the first time is a completely observed case of human scurvy under careful clinical, metabolic, chemical and dietetic control. The information should be widely studied; it enables the clinician to picture accurately the entire natural history of scurvy in one person. Analysis of the data will also resolve many disputed points which have resulted from uncontrolled observations. No doubt the experimental subject, when he returned to his regular diet, showed no deleterious effects of his experiences.

Vitamin C Value of Milk Is Widely Studied

Results of recent studies by many research workers indicate that fluid milk, raw and pasteurized, and evaporated, sweetened condensed, and dry milks, un-

der suitable conditions of handling and manufacture, are dietary sources of vitamin C of nutritional significance.

Krauss (5) estimates the vitamin C content of milk produced by cows on "ordinary dairy rations" at 25 milligrams (500 I. U.) per liter with losses of from 25% to 75% in pasteurized milk depending on how the milk was handled before pasteurization.

Holmes, Tripp, Woelffer, and Satterfield (6) reported in the Journal of the American Dietetic Association studies in which pasteurized milk averaged 14.03 milligrams of ascorbic acid per liter (this would be 13.27 milligrams per quart). The average loss from pasteurization was 18.71%. They summarized their studies as follows:

> A study was made of the ascorbic acid content of certified milk produced by a mixed herd of 175 Guernsey, Holstein and Ayrshire cows during an 18 months period.
>
> At bimonthly intervals samples were taken of the pooled milk from the entire day's production. Determinations of the ascorbic acid content were made by the indophenol method before and after pasteurization for 30 minutes at 143° F. in stainless steel spray vats.
>
> The raw certified milk was found to contain from 14.12 to 21.89 mg. or an average of 17.26 mg. of ascorbic acid per liter.
>
> The pasteurized milk was found to contain from 7.80 to 18.98 mg. of ascorbic acid with an average of 14.03 mg. per liter. The loss of ascorbic acid by the pasteurization process was greater in the warm, and less in the cooler seasons. The greatest loss was in August 1938 (53.25 per cent) and the least in March (4.53 per cent).
>
> The average loss of ascorbic acid from pasteurization was 18.71 per cent for the 18 months period.
>
> The results of this study show that a generous consumption of either raw or pasteurized milk, produced under ideal conditions, can contribute significant amounts of vitamin C to the daily diet.

Commercial Milk

Samples Analyzed

Workers at Wisconsin (7), comparing the ascorbic acid content of regular commercial samples of milk with the quantity present in the milk at the time of milking, found that milk taken directly after milking from Holstein, Brown Swiss, Jersey and Guernsey cows in the regular University of Wisconsin herd contained averages of 20.5 to 25.6 mg. per liter (19.3 to 24.2 mg. per quart). The analyses were made in January when the cows were on winter feed. Samples of commercial raw milk and commercial pasteurized milks from different dairies were analyzed. It was found that the ascorbic acid content of eight commercial raw unmodified milks ranged from 12.5 to 20.4 milligrams per quart and that of ten commercial pasteurized milks from 5.3 to 16.8 milligrams per quart.

Age of Cow, Stage of Lactation and Vitamin C in Milk

The age of a cow appears to have little relationship to the vitamin C content of the milk, Holmes and associates (8) reported as a result of assays of 659 samples of milk taken over a period of a year from cows ranging from four to eleven years old.

From a more recent study of the ascorbic acid content of cow's milk at various stages of lactation, these same workers (9) obtained values which are close to averages stated by other investigators. They reported values for milk from Guernsey cows as follows:

> . . . The average monthly values varied from 18.64 mg. per thousand cubic centimeters, in milk produced by 2 cows in the fifteenth month of lactation, to 21.95 mg. in the milk of 2 cows in the nineteenth month of lactation. The lowest and highest average values obtained during the ordinary commercial period of lactation were 19.39 mg. per thousand cubic centimeters, in milk produced by 18 cows in the eighth month of lactation, and 21.49 mg., in milk produced by 11 cows in the second month of lactation.

Corresponding data for Holstein cows were reported:

> . . . The average monthly values for ascorbic acid in the Holstein milk varied from 15.68 mg. per thousand cubic centimeters, in the milk of 2 cows in the first month of lactation to 20.11 mg., in the milk of 4 cows in the thirteenth month of lactation. However, the variation in the average monthly values for ascorbic acid during the stages of lactation typical of the average commercial dairy was from 15.68 mg., in milk produced during the first month of lactation, to 18.58 mg., in milk produced during the fifth month of lactation.

Evaporated and Powdered Milks Potentially Significant for Vitamin C

Both commercial powdered milks and commercial evaporated milks are potentially significant dietary sources of vitamin C, the Wisconsin group (10) concluded after analysis of 50 samples of these manufactured milk products. Their findings regarding evaporated milks, of which 41 samples were studied, are quoted, in part, as follows:

> . . . we find that the average American evaporated milk supplies 25% of the quantity of ascorbic acid found in freshly drawn cow's milk. . . . We have a range . . . of 1.9 to 13.8 mg. of ascorbic acid per liter. This range indicates that evaporated milk is potentially a significant source of ascorbic acid. Raw milk contains on an average 22.6 mg. of ascorbic acid per liter. This demonstrates that in certain of the samples of evaporated milk only about a 50% loss of ascorbic potency has occurred. The maximum value of 13.8 mg. per liter is not much lower than the average value of 17.3 mg. per liter, which we have reported for commercial raw milk, nor is it significantly different from the average value of 12.6 mg. per liter which we have reported for commercial pasteurized milk.

The Wisconsin workers pointed out that their analyses were made on samples of evaporated milk within 12 to 16 days after manufacture. Their studies did not include investigations of the effects of longer periods of storage.

Wisconsin results on powdered milks were reported, in part, as follows:

> . . . the ascorbic acid content of powdered milk is roughly equal to that of evaporated milks. . . . It appeared that neither the spray process, the roller process, nor even the mode of storage, is the significant factor which determines the ascorbic acid content of the powder. It is possible that, unless special precautions are used, a greater quantity of heat-labile dehydroascorbic acid is formed the more the powdered milk and powdered milk products are handled or modified. Thus, when the dehydration is brought about by heat, the destruction of the antiscorbutic potency is in direct proportion to the quantity of dehydroascorbic acid present. Consequently it appears that powdered milks are potentially a significant source of antiscorbutic factor if they are prepared from a milk which is rich in reduced ascorbic acid at the time of manufacture.

Other interesting indications from the data obtained by this group include the following:

> . . . the metallic nature of the manufacturing equipment is not the limiting factor which determines the ascorbic acid content of evaporated milk. . . . Evaporated milks manufactured almost entirely in copper equipment may contain more ascorbic acid than some evaporated milks manufactured almost entirely in stainless steel equipment.
>
> . . . the omission or inclusion of a pre-heating step in the process of manufacture is not important.
>
> . . . the ascorbic acid content cannot be correlated with geographical site of production of the evaporated milk.
>
> . . . the ascorbic acid content of irradiated evaporated milks is not significantly different from that of the non-irradiated.

The last point listed in the preceding quotations is in accord with results of experiments reported in 1931 by Dr. G. C. Supplee, of the Borden laboratories at Bainbridge, N. Y., and an associate, (11) which showed that ultraviolet irradiation in the production of vitamin D milk under suitably controlled conditions causes but slight destruction of the antiscorbutic vitamin in fluid milk and practically no destruction of vitamin C in dry milk.

Protecting Flavor and Vitamin C of Milk

The question of retaining the vitamin C content of milk is intimately involved with that of protecting milk flavor, since the causes of vitamin C destruction and the development of undesirable flavor are in many cases identical. Consequently dairy scientists in studying the imperative problem of protecting milk from flavor changes have simultaneously discovered valuable data concerning the protection of the antiscorbutic value of milk; and the dairy industry, in the practical application of methods developed by research for guarding flavor, at the same time is delivering to the consumer a product which tends to retain a larger proportion of the original vitamin C of freshly drawn milk.

The chief chemical process by which both the destruction of vitamin C and the development of undesirable flavor in milk occur is that known as oxidation —a mechanism involving changes in the positive and negative electric charges of ions, atoms, and molecules of the interacting substances through the transfer of electrons. Exposure to light, air and copper usually facilitates and hastens the oxidation, and the tendency to undergo oxidation is a chemical characteristic of vitamin C. Heat, in itself, is not a primary cause of the destruction of vitamin C, and heating to high temperatures under certain conditions may help protect both the flavor and the vitamin C of milk, experiments indicate.

Methods of protecting the vitamin C content of milk that have been investigated include the addition to the milk of minute quantities of chemical substances which act as a "bodyguard" in protecting the vitamin C from the chemical changes by which it is destroyed, or which act as a "proxy" or "double" for the vitamin C in that they take the place of ascorbic acid in the chemical reactions which otherwise would destroy the ascorbic acid itself.

One such method is the addition of a small amount of glutathione which either combines with the copper and thereby renders it inactive, or which itself undergoes oxidation and in this way spares the ascorbic acid. This has been studied by several workers. One of the latest studies on the subject is by Gould of Michigan State College (12) who reported that:

> The addition of 25 mg. per cent of glutathione to milk previously heated to 80° C. inhibited copper oxidation of ascorbic acid over a 48-hour period. Fifteen mg. per cent of glutathione was only slightly less efficient in preventing the catalytic action of copper.
>
> Although the glutathione prevented copper catalysis of the oxidation of ascorbic acid, it slowly disappeared from the system.

Another method that has been studied is the addition of chemically pure ascorbic acid, which two Wisconsin workers (13) reported as having an inhibiting effect on the development of oxidized flavor.

Another group of Wisconsin workers (14) more recently reported experiments in which vitamin C was added to milk, and from results of which they concluded that:

> . . . It is practical to produce a vitamin C-fortified milk on a commercial scale but the rigid exclusion of copper and protection from light are essential if the fortified milk is to be marketed through normal channels.

Much Technical Progress Reported

Some others of the many recent scientific reports concerning technical aspects of the protection of vitamin C in milk are mentioned briefly in the following paragraphs:

Research in England (15) and in California (16) has shown that opaque paper containers, protecting milk from exposure to sun, help preserve the vitamin C content.

Wisconsin data (14) indicated that milk in plain glass bottles which were carried on a regular enclosed delivery truck showed no losses of vitamin C in excess of those normally encountered when milk is stored in the dark. They interpreted this finding as indicating that in ordinary delivery of milk serious exposure to light probably does not occur.

Various degrees of heat in pasteurization have varying effects upon the vitamin C content and the flavor of milk, work by Michigan experimenters (17) indicated.

The entire subject of oxidation and flavor in milk and milk products was reviewed by West Virginia research workers (18) who concluded that elimination of copper contamination is one of the chief problems in protecting milk flavor.

Experiments by a U. S. Department of Agriculture dairy research man (19) indicated that oxidized flavor develops to a greater intensity at extremely low storage temperature.

Milk as a Food for Vitamin C

It is not the intent of this review to imply that milk, in the quantities in which it is ordinarily consumed, will provide optimum or even maintenance requirements for vitamin C in the human diet; rather, the significance of the vitamin C content of milk lies in the fact that whatever quantity of milk is consumed, if the milk has been handled with reasonable care, contributes its full proportional share to the total daily vitamin C intake, along with all the other nutritive substances for which milk is primarily consumed. This may be demonstrated by considering a hypothetical diet with milk as the sole article of food. An average, moderately active man, 20 to 49 years old, weighing 154 pounds, requires food providing an allowance of 3,000 net calories per day, according to the computations of Stiebeling and Phipard (20). If such an individual were to obtain his entire caloric requirement from milk, which averages approximately 680 calories per quart, he would consume 4.4 quarts of milk per day. If the milk were an average pasteurized market milk, containing as little as 5 mg., or 100 international units of vitamin C per pint, the 8.8 pints consumed would provide approximately 880 international units of vitamin C per day. This fulfills the daily requirement of 600 to 900 international units as calculated by Crandon, Lund and Dill (4).

If the original vitamin C content of the milk approached the maximum, and if it were handled under favorable conditions to protect against extensive vitamin C destruction the hypothetical diet of 4.4 quarts of milk per day could provide as much as 1760 international units of vitamin C per day—roughly double the approximate quota calculated by Crandon, Lund and Dill.

Since the total daily intake of all food of any individual is not unlimited, the practical significance of the data from this hypothetical all-milk diet lies

in the fact that milk is shown to be a food which may become a basic food for vitamin C when improved methods of handling and fortification with ascorbic acid have been perfected.

At present milk helps significantly to maintain or increase a positive vitamin C balance within the body. Many classes of foods represent energy value but contribute little or none of the antiscorbutic vitamin. Their use tends to reduce the vitamin C balance or even produce a negative balance.

Furthermore, individual food habits vary, and physicians and nutritionists have observed that even well-to-do individuals frequently may be victims of nutritional deficiencies through faulty knowledge or failure to select their foods wisely. The fact that a specific nutritive factor is abundantly available in a specific variety of food in itself is no assurance that the individual, as a matter of taste idiosyncrasy, lack of information, or circumstance, may not fail to consume appreciable quantities of such type of food with any degree of regularity. Despite the effectiveness of educational efforts there remain many individuals who habitually eat comparatively small quantities of fruits and vegetable products and who consequently should benefit from any increase in their total vitamin C intake toward optimum levels afforded by milk protected against vitamin C destruction or a milk of planned ascorbic acid content.

Balancing the Vitamin Intake with Milk

The importance of obtaining at least a portion of the daily vitamin C quota from the general diet, as well as from the foods which are primary and primarily vitamin C sources, is explained in the American Medical Association's Symposium in an article on sources of vitamin C by Dr. Otto A. Bessey (21) of the Harvard Medical School:

> For several reasons, effort should be made to conserve the vitamin C values of the general food supply rather than to depend on the use of foods of special antiscorbutic properties. A larger percentage of the people than is generally realized, because of economic conditions, lack of knowledge or poor food habits, do not include citrus fruits, tomatoes or other richly antiscorbutic foods in their diet. These people necessarily depend on the general food supply for their source of this essential. Also the loss of important food qualities, such as flavor and the content of other vitamins, usually parallels the destruction of vitamin C. . . .

Protective Levels of Vitamin C via Commercial Grades of Milk May Become Standard

Dr. G. C. Supplee, of The Borden Company Research Division (22), in summarizing recent investigations and current progress in developmental research designed to conserve the vitamin C in milk, states that the presence or absence of dissolved oxygen in milk now appears to be the critical factor in the

destruction or retention of the vitamin C of milk. This is indicated by data reported by Cornell workers (23, 24, 25) and from extensive data obtained from studies at The Borden Company Research Laboratories (unpublished data). Dr. Supplee summarizes the situation as follows:

> Investigations relating to the vitamin C content of fluid and processed milks have been primarily of a comparative character, involving objective determinations of the ascorbic acid content of milk subjected to usual processing procedures, with a given degree of experimental control of certain obvious variants known to affect the rate of destruction, such as heat, light, metallic catalysts and certain enzymes. Relatively few studies have emphasized or developed the significance of the dissolved oxygen content of milk as the basic factor accounting for seeming inconsistencies and variations in the results obtained. Such factors as elevated temperature, light, copper, etc. are secondary catalyzing influences contributing to the rate of destruction of ascorbic acid in milk only if dissolved oxygen is present. If the dissolved oxygen is removed, the vitamin C content of fluid and processed milks is stable notwithstanding subsequent heat treatment, exposure to light and the presence of copper contamination.
>
> Extensive data which interrelate the ascorbic acid content of milk and its dissolved oxygen content appear in the publications of Prof. P. F. Sharp and Associates of Cornell University and likewise, extensive data, as yet unpublished and accruing at the Borden Research Laboratories, Bainbridge, New York, incident to the study and development of methods for conserving in a practical manner the vitamin C inherent in milk as well as that which might be added as for example, in the preparation and distribution of fortified milk of predetermined vitamin C content.
>
> Although the methods for removing dissolved oxygen and conservation of vitamin C as proposed by Sharp et al and those developed by the Borden Research Laboratories, are different, both methods yield a milk free of dissolved oxygen and in which the vitamin C is stable so long as reabsorption of oxygen from the air is prevented. Milk deoxygenated by the method developed at the Borden Research Laboratories has been subjected to pasteurization temperatures as high as 185° F., even sterilized under pressure at temperatures as high as 268° F., exposed to strong light from a 3,000 watt carbon arc for three hours in the presence and absence of copper, without measurable destruction of vitamin C by any of these treatments. It may be concluded, therefore, that the overall practical and assured method for the conservation of vitamin C in milk is rather convincingly predicated upon the removal of the dissolved oxygen and prevention of its reabsorption from the air.

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